REMARKS/ARGUMENTS

Claims 1, 4, 5, and 17-19 were rejected under 35 U.S.C. §112, second paragraph. Reconsideration of the rejection is respectfully requested.

Claims 1 and 17 have been amended to overcome the rejection.

Claims 1, 4, 17, and 18 were rejected under 35 U.S.C. §103(a) as being unpatentable over Komatsu et al., JP 60052533 A, in view of Kurosawa et al., JP 03249138 A, either Druet et al., DE 2715423 C, or Morishita, JP 10-060550 A, Fujimoto et al., U.S. Patent No. 4,871,393, and Feichtner et al., U.S. Patent No. 4,410,355. Reconsideration of the rejection is respectfully requested.

Claims 5 and 9 were rejected under 35 U.S.C. §103(a) as being unpatentable over Komatsu et al. in view of Kurosawa et al., either Druet et al. or Morishita, Fujimoto et al., and Feichtner et al. and further in view of Noda et al., U.S. Patent No. 5,009,707. Reconsideration of the rejection is respectfully requested.

In support of the rejection of independent claims 1 and 17, the Examiner admits that, "Komatsu does not specifically teach that some of the returned sintered material is added alone 'within a longitudinal extent of a granulation drum' during the granulation process. Komatsu also does not teach that the returned sintered material is added in two different locations, such as both before the granulation drum and within the granulation drum, as stated in instant claim 1," (Office Action, page 3, lines 8-12). However, the Examiner contends that, "Druet, in a similar invention of sintering ore, shows sintered material being delivered directly back into the granulation device (Figure 1). Morishita, in a similar invention of sintering ore, shows return fines fed directly back to the discharge end of the drum mixer (Figure 1)," (Office Action, page 3, lines 13-16). In addition, the Examiner contends that, "Kurosawa, in a similar invention, teaches that some of the returned sintered material may be brought back to both before the first mixer as well as just before the secondary pelletizing mixer (Figure 1)," (Office Action, page 4, lines 1-3).

Applicants respectfully disagree with the Examiner's analysis. In particular, Druet appears to disclose that recycled fines from a process of firing a mixture of ores and solid fuel are recycled over a path 12 into a starting mixture prepared at station 1. The starting mixture at station 1 includes the ore to be aggregated and solid fuel, and in station 1 water is also added to

the mixture of ore and fuel (nodulization of the mixture), (English language equivalent of Druet, GB 1 574 647, copy enclosed, page 4, lines 43-92; Fig. 1). Thus, the recycled material appears to be returned to a station in which mixing and nodulization or granulation of the mixture occurs. In contrast, independent claims 1 and 17 require a granulation drum for granulation and a separate container for mixing. Furthermore, independent claims 1 and 17 provide for addition of returned sintered material after the ore has been mixed with the at least one addition and optionally with the binder. In contrast, Druet contemplates the addition of the returned sintered material into the starting mixture prepared at station 1, as previously mentioned.

With regard to Morishita, Morishita only appears to disclose the return of granulated fines, but not the return of sintered fines to a drum mixer. The computer generated English translation of Morishita, attached to the Office Action, states, "[t]he granulation method of the sintering raw material of this invention is applied to the granulation installation 1 as shown in drawing 1. First, after the rolling granulation of the sintering raw material cut down from the raw material tub 2 is carried out with the 1st and 2nd drum mixer 3 and 4, it is classified in coarse grain and a fine grain with the classifier 5. And among the granulation things classified with the classifier 5, coarse grain is conveyed on the band conveyor 6 to the sintering machine 7, and is made with sintered ore. On the other hand, after a fine grain passes a kneading treating part or the mixed agitation treatment part 8, it carries out rolling granulation with the 3rd drum mixer 9, and it circulates through it to the discharging end part of the 2nd drum mixer 4 again," (page 7, paragraph [0027], lines 1-9; emphasis in original).

Finally, with regard to Kurosawa, Kurosawa only discloses the return of sintered ore to a storage tank 2, which is then fed with other materials to a primary mixer 3, and the return of sintered ore before a secondary mixer 4 in which the mixture is pelletized, (Fig. 1; English language abstract attached to Office Action). Thus, all Kurosawa shows is the addition of sintered ore to a mixture before pelletization, which may perhaps be equated to granulation, occurs, and also return of such sintered ore to a tank before initial mixing of components occurs. The return of the sintered ore to a tank to allow the sintered ore to be mixed in a primary mixer with other components is contrary to the requirement of independent claims 1 and 17, that the sintered ore be added after mixing of other materials. Furthermore, the return of sintered ore before secondary mixing, which is perhaps equivalent to granulation, only discloses at most part

of the requirements of independent claim 1 of the addition of such sintered ore both before the mixture enters the granulation drum and to the granulation drum during granulation of the mixture. Such return also is completely contrary to the requirements of independent claim 17 that all sintered material be returned within the longitudinal extent of the granulation drum during the granulation of the mixture.

Since each of claims 4, 5, 18, and 19 is directly dependent on one of independent claims 1 and 17, each of claims 4, 5, 18, and 19 is allowable for at least the same reasons recited above with respect to the allowability of the appropriate one of independent claims 1 and 17.

New independent claim 20 has been added. New independent claim 20 is based upon independent claim 1, as amended herein, except that the phrase "adding some of the returned sintered material alone within a longitudinal extent of the granulation drum during the granulation of the mixture" in claim 1 has been changed to --adding some of the returned sintered material alone within a longitudinal extent of the granulation drum during the granulation of the mixture and before completion of granules of the mixture, completion of the granules of the mixture occurring upon sheathing of the granules with a fuel during the granulation of the mixture-- in claim 20.

New independent claim 21 has also been added. New independent claim 21 is based upon independent claim 17, as amended herein, except that the phrase "all of the returned sintered material being added alone within a longitudinal extent of a granulation drum during the granulation of the mixture" in claim 17 has been changed to --all of the returned sintered material being added alone within a longitudinal extent of a granulation drum during the granulation of the mixture and before completion of granules of the mixture, completion of the granules of the mixture occurring upon sheathing of the granules with a fuel during the granulation of the mixture-- in claim 21.

Antecedent basis for new independent claims 20 and 21 is found in the specification, for example, on page 3, lines 12-15, on page 7, lines 11-18, and on page 8, lines 6-9.

In view of the foregoing amendments and remarks, allowance of claims 1, 4, 5, and 17-21 is respectfully requested, claims 7-16 having been withdrawn from consideration.

Respectfully submitted,

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(19)

(54) A FIRING METHOD AND PLANT FOR FIRING A MIXTURE OF METALLIC ORES

(71) We, SACILOR ACIERIES ET LAMINOIRS DE LORRAINE, of 6 Rue de Wendel, 57704 Hayange, France, a French company, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in the following statement:—

The present invention relates to a method of firing a mixture of metallic ores and solid fuels.

The method of the invention is applicable to continuous aggregate conveyors particularly to those used in iron and steel metallurgy in order to aggregate fine iron ores.

The invention relates equally to an ore aggregation plant. This may suitably be of the type comprising a mixing and nodulizing station, an endless conveyor comprising a series of receiving elements with a grating circulating in a continuous manner between a mixture charging station and a discharging station, reduced pressure means establishing circulation of the gas through the beds contained in the receiving elements of the upper run of the endless conveyor, and a firing hood, which is arranged above a portion of the upper run of the said conveyor and includes burners.

Methods previously thought of for firing the iron ore mixtures possibly made up of calcareous rocks and solid fuels, such as coke, coal dust, coal fines etc., intended essentially to ignite the solid fuel contained in the upper part of the bed of these mixtures in order that the process of aggregation by means of fritting could then develop naturally under the action of combustion of the solid fuel maintained by suction of air downwardly through the bed.

In order to do this the existing firing methods sought to produce hot gas at a level of temperature and over a length of conveyor such that the solid fuel included in the upper part of the bed of the mixture to be aggregated could ignite.

In these known cases quantities of gaseous or liquid firing fuel and combustion supporting gas are admitted by the burners into the firing hood without any particular pre-occupation other than good functioning of the burners, the combustion supporting gas to fuel ratio in the firing space of the firing hood being generally controlled in accordance with stoichiometry.

This known technique exhibits the following disadvantages.

a) The upper portion of the bed is incompletely and insufficiently fritted because, particularly owing to calorific loss as a result of radiation of the surface of the mixture once fired, the combustion of the solid fuel in the mixture to be aggregated does not permit complete fritting of the said upper part of the bed. Moreover, this upper part does not benefit from transfer of heat owing to the permeating gases as do the lower parts of the bed, said permeating gases removing heat stored in the upper parts of the bed already aggregated and transferring it to a part of a lower bed. Thus this upper part of the bed is not able to attain a level of temperature which is as high as the other parts of the bed. This leads to lesser fritting of this upper part of the bed which corresponds to a large proportion of recycled fines reducing the aggregate production of the plant by this amount and increasing the thermal consumption per tonne of aggregate sold, i.e. per tonne of aggregate which may be used directly in a blast-furnace.

b) A second disadvantage of this method consists in a high degree of transverse heterogeneity of the firing of the bed. In fact, as the rate of delivery of hot gas supplied by the burners of the firing hood is not matched in all places to the rate at which the gases pass through the bed (practice shows that it is in some places less), then within the firing hood there is a reduced pressure at certain areas which leads to the introduction of parasitic air into the said hood. This introduction of parasitic air occurs through the interstices located

between the firing hood itself and the edges of the receiving elements charged with the mixture to be aggregated. This introduction of parasitic air cools down the hot gas from the firing burners by mixing with it, and this leads to a less effective firing of the parts of the mixture situated below the firing hood at the lengthwise extending edges of the aggregate conveyor; this disadvantage may be confirmed in all the aggregate plants using the known above-mentioned technique.

Another firing method equally well known and entitled "prolonged firing" comprises supplying the mixture bed with supplementary calories after the firing operation in the form of hot gases produced in a second hood following the first. This type of method has the advantage of replacing the calories issuing from the solid fuel by the calories coming from the gas or liquid fuel.

But this known method also exhibits disadvantages:

a) It leads to low productivity of the aggregate conveyors because it increases the thickness of the combustion region at a high temperature in the mixture bed, which in itself creates a greater resistance to the passage of combustion supporting gas through the bed, and in these circumstances combustion of the fuel in the layer takes place more slowly and this reduces the productivity of the process.

b) This method requires supplementary investment in the form of a second hood equipped with burners as is the first, and this has the additional disadvantage of multiplying the number of burners.

c) Implementation of this known method requires the use of gaseous or liquid fuel with a high calorific value, therefore they are expensive. In fact, the gases must be at a sufficient temperature and must contain sufficient oxygen in order that the combustion of the solid fuel included in the mixture to be aggregated may continue to develop beneath the second hood.

d) This known method leads to an increase in the heat stored in the aggregates drawn from the furnace, i.e. at the end of the conveyor, and this makes it necessary to employ a cooler of a greater capacity.

A third known method inspired by the previous method involves blowing of hot air instead of hot combustion gases through the bed to be aggregated after the firing operation. This hot air is obtained for example with the aid of regenerators of the "cowper" type.

This third known method certainly makes it possible to use a fuel having a relatively low calorific value, such as blast-furnace gas, in order to heat up the air of the second hood. However, it does not prevent a reduction in productivity of the aggregate conveyor, a reduction which is due, again, to an increase in the thickness of the combustion region which is at a high temperature, and to the above mentioned disadvantages resulting therefrom. In addition, implementation of this method necessitates a large investment for the additional hood and heat exchangers of the "cowper" type.

The present invention seeks to at least reduce the disadvantages cited above by reducing the total thermal consumption of the aggregate conveyors with means requiring only relatively low investment.

According to a first aspect of the invention, there is provided a method of firing a mixture of metallic ores and solid fuel comprising passing a bed of the mixture under a firing hood equipped with burners, maintaining a reduced pressure beneath the bed to draw firing gas from the hood burners through the bed, and supplying the burners with a fluid fuel and a combustion supporting gas containing oxygen, the delivery of firing gas to different regions in the hood being varied from the hood entrance to the hood exit in dependence on the permeability of that part of the bed below that region of the hood such that the pressure in the hood is maintained substantially constant, slightly above the ambient pressure, over the length of the hood.

Preferably the temperature of the firing gas is maintained between 1250°C and 1500°C by modifying the relationship between the delivery of fluid fuel and combustion supporting gas.

Preferably each cross-section of the bed is subjected to the firing operation during its stay beneath the hood for a period of between 30 seconds and 200 seconds.

As a result of these measures, remarkably homogeneous fritting or aggregation of the mixture can be achieved over the entire width and throughout the entire thickness, including the upper part of the mixture bed. Moreover, this results not only in a gain in the production of saleable aggregates and a corresponding reduction in the recycled fines, but also in an improvement in the quality of the aggregate thus manufactured.

In fact, subsequent to granulometric examination of aggregates manufactured in accordance with the method, these being ground in a MICUM drum having carried out 30 rotations, it has been confirmed that the mean particle size of the total product is very large and there is very little less than 5 mm.

The advantages resulting from the method in accordance with the invention are not limited to the formation of aggregates but relate also to a reduction in

the thermal consumption. Thus it has been possible to confirm that a proportion of the heat generally produced with the aid of the solid fuel contained in the mixture bed could be replaced by a smaller quantity of heat but produced by the firing fuel, despite the fact that this increases the thickness of the combustion region. In fact it has been proved that the heat stored in the aggregate at the moment of being drawn from the furnace is not greater than values measured in the case of the first-mentioned known method. This explains, moreover, the good rates of thermal replacement which may be obtained with the method of the invention for Lorraine-type ores, these rates varying from 3.3 to 2.3 when the reduced pressure below the mixture bed varies from 600 to 1400 mm water column at the position of the firing hood. Thus it has been possible to replace 5 kg of dry solid fuel per tonne of aggregate, equivalent to 38 therms, and normally incorporated in the mixture bed, by only 17 therms produced in the firing hood by the firing fuel. In other words, as a result of the invention, the total thermal consumption may be lowered by more than 20 therms per tonne of saleable aggregate.

In accordance with a preferred feature of the invention, each cross-section of the bed is subjected to the firing operation for a period of between 50 and 70 seconds and preferably of the order of 60 seconds. This contributes to obtaining an optimum total productivity.

In order to avoid any premature compression of the mixture bed and thus any diminution in the permeability of the said bed, the lower face of the mixture bed is only exposed to the action of the reduced pressure from the beginning of the passage of the said bed beneath the firing hood, at which time the said mixture is subjected to the action of the firing gas. In this way the mixture bed is fired practically as soon as the firing gas begins to be sucked through the said bed.

In one embodiment of the invention the variation in delivery of firing gas to different regions of the hood is obtained using the same number of burners in each region, the burners having variable outputs or different outputs from one another. In another embodiment the variation in delivery of firing gas to different regions of the hood is obtained with burners which all have the same output by providing a different number of burners in each different region.

In order to keep the slight overpressure constant beneath the firing hood it is preferred that initially determined values of the delivery and temperature of firing gas are maintained during performance of the method and adjustments are made only by varying the reduced pressure applied to the lower face of the portion of bed located beneath the hood.

According to another aspect of the invention, there is provided plant for firing a mixture of metallic ores and solid fuel comprising a firing hood, means for transporting a bed of the mixture under the firing hood, burners in the firing hood for producing firing gas from fluid fuel and combustion supporting gas supplied thereto, means for producing a reduced pressure beneath the bed to draw firing gas from the hood burners through the bed, and means for feeding a fluid fuel and a combustion supporting gas to the burners in such a way that, together with the arrangement of the burners, the delivery of firing gas to different regions in the hood varies from the hood entrance to the hood exit in dependence on the permeability of that part of the bed below that region of the hood such that the pressure in the hood is maintained substantially constant, slightly above the ambient pressure, over the length of the hood.

With such plant it is possible to match the rate of delivery of firing gas without difficulty to the varying permeability of the charge along the length of the hood, thereby avoiding local overheating which could be caused by possible licking (by flames) of the mixture bed by the flames of the high output burners.

In certain cases it could be advantageous to mount at least the burners nearest the entrance end of the firing hood so as to be adjustable in height.

Instead of burners the firing gas outputs of which vary from one row of burners to the next it is also possible to use burners which all have the same output and which are grouped in different numbers so that the delivery of firing gas varies from one group of burners to the next in dependence on the permeability of the cross-section of the mixture bed which is located in line with each group of burners, the number of burners per group of burners diminishing from the entrance end towards the exit end of the firing hood.

In a firing hood the burners of which all have the same output of firing gas, it is also possible to arrange the burners in rows each having the same number of burners; in this case however the distance between adjacent rows of burners increases from the entrance end towards the exit end of the firing hood so that the overall delivery of firing gas from each row of burners is matched to the mean permeability of the cross-section of the mixture bed with which each row of burners is associated.

The invention will now be described in greater detail, by way of example, with reference to the drawings, in which:—

Figure 1 is a schematic view of an aggregation plant in accordance with the invention;

Figure 2 is a schematic view of the mixture bed and of the combustion zone of the said bed;

Figure 3 is a diagram showing the relationship between the variation with the time of the hot permeability of a cross-section of mixture bed beneath the firing hood and the associated variation with time of the required delivery of firing gas in the firing hood at the region where that cross-section is located; this can also be considered as the corresponding variations along the length of the hood since the mixture bed is transported therethrough during firing;

Figure 4 shows schematically a device making it possible to establish the hot permeability curve of a cross-section of mixture bed, as a function of the firing time;

Figure 5 is a plan view of the firing hood with the burners arranged according to a first scheme;

Figure 6 is a plan view of the hood with the burners arranged according to a second scheme;

Figure 7 shows a plan view of the firing hood with the burners arranged according to a third scheme;

Figure 8 shows the temperature curves of three points situated at different levels in the mixture bed and having undergone firing in accordance with the recommendations of the IRSID: and

Fig. 9 shows the temperature curves of three points situated at the same levels of the mixture bed as the points cited in connection with Figure 8 but this time the mixture bed has been fired in accordance with the method according to the invention.

The aggregation plant shown in Figure 1 comprises a station 1 in which the ore to be aggregated and solid fuel are introduced in separate form and are mixed together in a homogeneous manner. In the station 1, water is also added to the mixture of ore and fuel (nodulization of the mixture). Finally, in this same station 1 are incorporated into the mixture the recycled fines, i.e. the ores of too small a grain size which have fallen through screens at hot and cold sifting stations 10, 11 after having passed through the plant. The mixture thus prepared is charged at as indicated by the arrow 2 i.e. at the beginning of the upper run of an endless conveyor transport device 4, into receiving elements 3 such as containers arranged on carriages and having a bottom grating mounted one after another on the endless transport device 4. The mixture of ores and solid fuel contained in each container or carriage 3 is called a bed. Each bed of mixture passes below a firing hood 5 provided with burners 6 and is fired there. Between the side edges of the container 3 and the upper face of the beds on the one hand, and the lower edges of the hood on the other hand, are provided impervious elements which prevent any significant entry of air into the said hood. Forced circulation of hot gas and combustion supporting gas through the beds contained in the carriages 3 is obtained by means of suction devices 7 arranged beneath the path of the carriages 3 circulating on the upper run of the conveyor device 4. The air-tightness between the lower side edges of the containers 3 and the upper edges of the suction devices 7 is achieved by means of air-tight joints.

The aggregated beds contained in the containers 3 are discharged at 8, i.e. at the end of the upper run of the transport device 4, onto a crusher 9. Screens at the hot sifting station 10 and the cold sifting station 11 make it possible to eliminate aggregates of too small a dimension, called recycled fines, which are recycled over a path 12 into the starting mixture prepared at station 1 as mentioned above.

The firing operation of the mixture bed 13, which is subdivided along its length by the containers 3 but which may be considered as a continuous bed from one end to the other of the upper run of the endless transport device 4, starts close to the entrance to the firing hood 5. In order to simplify the description of the invention, the mixture bed 13 is subdivided in an imaginary fashion into a plurality of juxtaposed cross-sections which are each transported at a constant speed from one end of the upper run of the endless device 4 to the other. This speed of advance or transportation is regulated chiefly as a function of the density H of the bed 13, and of the reduced pressure applied to the lower face of the bed such that the combustion front 14 of the combustion zone 15 has completely traversed from top to bottom the cross-section under consideration of the mixture bed 13 by the time the section arrives at the end of the transport device 4. A reduced pressure Δp is applied to the lower face of the mixture bed 13 from its entrance beneath the firing hood 5 until almost the end of the transport device 4, said reduced pressure being 300 mm to 2000 mm and preferably 1400 mm water column less than the pressure prevailing at the upper face of the said mixture bed 13, this reduced pressure Δp being obtained by fans installed in the suction devices 7.

The burners 6 of the firing hood 5 provide part of the mixture bed 13 with a predetermined volume of firing gas, that is a gas comprising in part the hot combustion products from the fuel and in part hot

combustion supporting gas supplied in excess to the burners 6. The part of the bed receiving the firing gas is that part delimited by the area covered by the hood 5. This area can be subdivided in an imaginary or notional fashion into several regions, the delivered volume of firing gas giving each of the said regions a predetermined quantity of heat which is used for the most part in order to fire the mixture bed at this region, but which is also used for applying heat to the mixture bed in the regions beneath the hood 5. The mixture bed in these regions has a combustion zone 15 which progressively moves away from the upper face of the mixture bed 13 beneath the hood 5 as the mixture bed passes through the hood (see the right-hand side of the hood 5 shown in Figure 2). In fact this supply of heat avoids a too rapid cooling and incomplete aggregation of the upper part of the mixture bed 13. In Figure 2 it is above all the burners 6 of the row of burners situated in the vicinity of the outlet of the hood 5 which ensure this additional contribution of heat to the upper face of the mixture bed which has already been aggregated, just before the mixture bed passes out of the hood 5.

The heat provided by the burners 6 of the hood is conveyed by the firing gas through the portion of the mixture bed located immediately beneath the burners 6 within said hood 5, and this takes place in such a way that the pressure prevailing beneath the hood 5 is uniform throughout the length of the hood taking into account the reduced permeability of the mixture bed towards the exit end of the hood 5. The pressure in the hood 5 is very slightly above the ambient pressure prevailing outside the said hood 5. This measure avoids the suction of cold air from the outside into the inside of the hood 5 at the places where spacings exist between the lower edge of the hood 5 and the upper edges of the containers 3. The firing gas provided by the burners 6 is composed generally of hot combustion products and hot combustion supporting gas, which latter may include or comprise air. The burners 6 are thus supplied by a mixture of gaseous or liquid fuel and a combustion supporting gas such as air, the combustion supporting gas always being supplied to the burners in excess of the stoichiometric quantity. In fact, the amount of combustion supporting gas supplied to the burners 6 can be adjusted in order to control the temperature of the firing gas in order to obtain the desired value which lies between 1250°C and 1500°C. For ores of the Lorraine type, the measured temperature of the firing gas is preferably of the order of magnitude of 1350°C. The required excess of combustion supporting gas depends chiefly on the nature of the fuel to be burnt. Of course once the volumetric ratio between the gaseous or liquid fuel of a given calorific value and the combustion supporting gas has been determined in order to obtain a desired temperature of firing gas, this ratio is maintained at a constant level and only the total volumetric output of the fuel combustion supporting gas mixture is adjusted subsequently, should the need arise for such adjustments.

It has been confirmed that, in order to realize a pressure which is substantially uniform along the length of the hood 5, the delivery of firing gas should not be uniform along the hood but should vary along the hood in dependence on the local permeability of the mixture bed under consideration. If a cross-section of a mixture bed of a predetermined composition is taken and if its permeability A is determined experimentally at the ambient temperature then a value A_F will be obtained which will be called "cold permeability". In order to determine the permeability A and thus at the same time the output Q of the firing gas capable of passing through a mixture bed of a given surface and thickness H, it is possible to use the device shown schematically in Figure 4. This device comprises a vat 16 which is cylindrical or parallelepipedic, for example, in cross-section as known and is provided with a grating 17 at the bottom below which a collector 18 is fixed in an air-tight manner, said collector 18 being connected to a vacuum pump 19 such as a fan. Above the vat 16 it is possible to provide a volumetric delivery meter 20. The vat 16 is full to a certain height H corresponding to the thickness of the mixture bed 13, with the mixture of determined composition 21. In the space 22 located above the mixture 21 there is located at least one burner 23 having a variable output and which is connected to a differential manometer 24 which indicates the difference in pressure between the pressure in the space 22 and the ambient pressure. The burner or burners 23 are fed by a mixture of gaseous fuel arriving through a pipe 25 and a combustion supporting gas, such as air, arriving through the pipe 26 provided with an adjustable valve 27 and opening into the axial entrance to an adjustable venturi duct 28. The pipe 25 for the gaseous fuel opens into the sidewall of this duct 28 at the constricted part thereof. The outlet of the venturi duct 28 is connected by a pipe 29 to the burner or burners 23 and the upper end of the vat 16 is hermetically sealed by a lid or cover 30, the pipe 22 passing through it in an air-tight manner. The collector 18 below the bottom grating 17 is also connected in an air-tight manner to the vat 16 and the space delimited by the collector 18 is

connected to a manometer 31. The delivery meter 20 is mounted preferably on the air conduit 26 and it measures the proportional delivery of air to the delivery Q of the firing gas.

The mode of use of the device in Figure 4 is as follows:—

When the volumetric relationship between the quantities of fuel and combustion supporting gas for the burner 23 to produce a firing gas of a predetermined temperature, for example 1350°C, has been determined by adjusting the venturi duct 28, the position of the adjustment member of the duct 28 is fixed. The lower face of the mixture bed 21 is subjected to a reduced pressure of a predetermined value, for example, 1400 mm water column, at the same time a sufficient volume of air is delivered to the burner 23 so that the pressure in the space 22 is maintained just slightly above ambient pressure or the difference in pressures indicated by the manometer 24 is slightly above zero. At the same time, the delivery of air is measured by the output meter 20. The delivery of air is a significant value making it possible to determine the cold permeability A_F by means of Darcy's law. It should be noted that it is important to carry out this measure very rapidly in order not to compress the mixture 21 and to lower its permeability. As soon as possible after determining the cold permeability A_F carried out at the time $t=0$, the burner or burners 23 are fired and the firing gas is sent into the space 22 at the temperature T=constant at an output Q so that a slight overpressure exists in relation to the ambient pressure for a maintained reduced pressure which is equally constant in the collector 18, maintained with the aid of a vacuum pump 19. While the firing gases fire the mixture 23, the combustion zone is established in the mixture and the mixture is aggregated until the combustion front has passed through the mixture from the top to the bottom as far as the grating 17, the hot permeability A_C diminishes progressively like an exponential function and the output of firing gas Q passing through the mixture should also diminish in the same manner if the slight over-pressure is to be maintained at a constant level in the space 22 above the mixture 21. Therefore, it is sufficient to trace the exponential curve C_1 in a system of rectilinear coordinates recording on the ordinate the values of instantaneous delivery as measured by the volumetric delivery meter 20 as a function of the time t as an abscissa and drawn from the time of measurement of cold permeability A_F or more precisely from the beginning of feeding the firing gas into the vat 16.

The curve C_1 shown in Figure 3 shows that the hot permeability of the mixture bed 21 and the instantaneous output in firing gas diminishes like an exponential function and approaches a limit value in an asymptotic manner as a function of the period of firing t. This curve C_1 also shows that the larger output of firing gas should be provided the first moments of the firing operation and that the duration thereof must be fairly short, of the order of several dozen to one or two hundred seconds, for example from 30 to 120 seconds, if one wishes to avoid loss of productivity. Moreover it has been confirmed that for ores of the Lorraine type, firing periods of the order of one minute will give optimum results. It has been proved in practice that in a plant such as that shown in Figure 2 the firing gas does not distribute itself across the region above the mixture bed 13 automatically as a function of the permeability of the mixture in the different regions of the mixture bed under the hood. In fact, practice shows that at a region of the mixture bed fed by insufficient firing gas for the permeability of the said section, there is no drawing of firing gas from the adjacent regions of the hood to the said region under consideration but rather cold external air is drawn into the hood at this region. Therefore it is proposed to provide the hood 5 either with the burners whose outputs are adjustable over a large range of outputs or with burners at a constant output or only slightly variable but in different numbers for each region of the hood so as to be able to adapt the delivery of firing gas to the permeability of the cross-section temporarily in association with a given region of the hood.

The length L of the hood 5 is determined as a function of the speed of transportation v of the mixture bed beneath the hood and the firing period t_f of the said bed once the value A_g of the permeability A which the mixture bed 13 should have at the exit of the hood 5 is fixed.

Since, in practice, instead of the mixture 21 located in the experimentation device in accordance with Figure 4 a continuous bed of mixture is used comprising juxtaposed cross-sections which are displaced at a constant speed from the entrance to the exit of the hood 5 and more precisely from one end to the other of the transport device 4, the hot permeability of a cross-section varies from the entrance up to the exit of the hood 5. Since a given cross-section of the mixture bed is displaced relative to the hood 5 and its burners 6 the output of a given transverse row of burners 6 is matched to the average permeability of the transverse section of the mixture bed at the location of this row, that is to the permeability which it will have when it is located in line with the location of the row of burners under consideration. It is possible to subdivide the

hood 5 into several successive notional transverse areas *a, b, c, d, e, f,* in an imaginary manner, these areas being of identical width along the length of the said hood. the area *a* being situated at the entrance end and the area *f* being situated at the exit end of the hood 5 (see Figure 3). As may be seen in Figure 5 a row of burners 6*a* to 6*f* are envisaged in the median transversal plane of each notional area *a, b, c, d, e, f,* the outputs 2*a* to 2*f* of said row of burners corresponding to the average permeability of the cross-section with which these rows of burners are associated locally in the hood 5. The curve C_2 in Figure 3 representing the burner outputs varies abruptly from one area of the hood to another like a set of stairs.

In order to take into account the fact that the burners of the rows 6*a* and 6*b* have an output much higher than those situated close to the exit end of the hood 5, and that in consequence the length of their flames is larger, it is appropriate to arrange them at a greater spacing from the upper face of the mixture bed 13 than that existing between the said upper face and the burners 6*f* situated close to the exit end of the hood 5. The burners may be mounted so as to be adjustable in height to this end (see also Figure 1).

It is also possible to use burners the output of which is not adjustable or only slightly adjustable and which is identical for all burners. In this case it is possible to subdivide the hood 5 in an imaginary or notional fashion into several transverse regions *a′, b′, c′*, as shown in Figure 6, receiving the same overall delivery of firing gas, but the area of these regions increasing along the length of the hood between the entrance and exit ends thereof. Nevertheless it is necessary to see that, in this case, the distance between two successive rows of burners, for example, 6*a′* and 6*b′* or 6*b′* and 6*c′* does not become too large, each row of burners 6*a′*, 6*b′*, 6*c′* having the same number of burners and being placed in line with the median transverse plane of the corresponding region. In the case shown in Figures 3 and 6 the delivery of firing gas, 2*a* to the area *a′* is identical to that which the area *a* of the hood receives in accordance with the example of Figure 5; but the delivery to the area *b* is equal to 2b+½ 2c and the delivery to the area *c′* is equal to (½ 2c+2d+2e), the hood 5 in accordance with Figure 6 being shortened and not having a region corresponding to the region f of Figure 5.

It is equally possible to subdivide the hood 5 in an imaginary or notional fashion into regions of identical area *a″, b″, c″, d″, e″, f″*, that is regions having equal width (along the length of the hood 5) while using burners having non-variable or slightly variable output. In this case the rows of burners 6*a″*, 6*b″*...6*f″* are arranged each in the transverse median plane of a corresponding area of the hood 5, but the number of burners in the rows diminishes from the row 6*a″* located close to the entrance end of the hood to the row of burners 6*f″* situated close to the exit end of the hood 5. It is obvious that in this case, adapting the actual delivery from the burners to the theoretically required delivery is not possible in a completely precise fashion and an error above or below is possible depending on the value of the nominal output of a burner. These imprecisions in the deliveries of firing gas could lead to pressure values which are too high or too low beneath the hood 5. Thus the pressure beneath the hood 5 is regulated to its set value preferably by modifying the value of the reduced pressure below the mixture bed, by either increasing or reducing it until the required set value of hood pressure is obtained.

It is apparent from the above that the combustion supporting gas-to-fuel ratio fed to the various burners may either be regulated in toto on the total delivery through the burners or better still it may be regulated for each transverse row, i.e. for each area of the hood.

The height of the hood should take into account the type of burners employed and the type of mixture to be aggregated. This height may be variable along its length; it is advantageous if it is larger towards the entrance end of the hood, taking into account the longer flames at this region, because of the higher delivery of firing gas at this point (Figure 1). In accordance with the embodiment of Figure 1 the burners 6 are regulated and fed such that the flames which they emit are of decreasing length in the direction of displacement of the containers 3.

By way of example the results obtained in the laboratory on the experimental tank by using the firing process which is the subject of the invention, are given below. In this case the reduced pressure during the course of aggregation is 1400 mm water column and the thickness of the bed H is 50 cm. The mixture used is a mixture of ores from Lorraine; these tests are balanced at 500 kg of recycled fines per tonne of saleable aggregate; the solid fuel incorporated in the mixture of ore is constituted by fines of a calorific value less than 7.6 therms/kg. The reference method corresponds to the operating method used by l'Institut de Recherches de la Siderurgie Francaise (IRSID) the operating method which has been standardized in thermal consumption and productivity on the No. 1 aggregate

conveyor Rombas of the company Sacilor and is described for example in the IRSID Report of July 1973 on page 207, entitled "Comparaison et resultats obtenus en laboratoire et sur chaines industrielles dans le cadre de l'agglomeration sur grille" ("A comparison and the results obtained in a laboratory and on industrial conveyors within the framework of aggregation on a grating") by Messrs. Didier and Ivanier.

The results were as follows:

	Reference Test	Firing in accordance with the invention		
Reduced pressure during aggregation in mm water column	1,400	1,400	1,400	1,400
Reduced pressure under the conveyor during firing in mm water column	varying from 200 to 800	600	1,000	1,400
Consumption of dry fuel in kg/t	81.8	79.7	77.5	76.7
Productivity t/m2/24h	22.8	22.3	23	21.7
Heat consumption				
Solid fuel therms th/t	621.7	605.7	589	582.9
Firing (gas) th/t	40.6	45.4	53.8	57.6
Total th/t	662.3	651.1	642.8	640.5
Rate of replacement (yield) th of solid fuel / th of firing gas		3.3	2.5	2.3
(Grain size) median (mm)	15.25	15.6	15.65	16
<5 mm after 30 turns Micum %	25.5	24.4	23.7	24.7

CE: water column
t: tonne of saleable aggregate
th: therms

Another special experiment carried out, this time with a mixture bed having a thickness of 40 cm and with 1400 mm water column of reduced pressure is illustrated in Figures 8 and 9. In this case thermocouples were introduced at three different levels in the charge to be aggregated and the temperatures at the junction of the different thermocouples were measured during the following operation and the following aggregation process. The three curves C3, C4, C5 and C'3, C'4, C'5 in Figures 8 and 9 show the variation of the temperature of the thermocouples at 30 cm (curves C3 and C'3) as a function of the firing time and as a function of aggregation t, at 20 cm (curves C4 and C'4) and at 10 cm (curves C5 and C'5) from the bottom grating on which the mixture bed rests. Two aggregation tests were performed one with the reference firing conditions and one with the method of firing in accordance with the invention, the reduced pressure below the grating having been 1400 mm water column at the time of firing and aggregation.

The temperature curves C3, C4, C5 and C'3, C'4, C'5 make it possible to see that the gradient and the envelope of the curves C5, C'5 corresponding to the thermocouples situated at 10cm of the grating are quite similar (same scale of temperatures). Taking into account the aggregation speeds corresponding to the two tests it is possible to confirm, by means of planimetering, that the heat stored by the aggregate at this level is almost identical for both tests.

It should be noted that in this case the difference in dry solid fuel consumption is 7 kg/t for yields similar to those obtained for 50 cm thickness of the bed.

It is also possible to see in Figures 8 and 9 the difference in envelope of the two curves C3 and C'3 corresponding to the thermocouples situated at 20 cm from the grating. This difference illustrates very clearly the additional thermal contribution procured by the method of firing advocated in this invention.

It is obvious that, because of the variety of ores capable of being subjected to the method in accordance with the invention, it is not possible to give a precise formula for calculating the different deliveries of firing gas to be used in different regions under the hood, these outputs not being capable of determination except experimentally in accordance with the previously described method. It is obvious that the results of experimentation must be adapted to the dimensions of the aggregation conveyor, particularly to the actual width of the mixture bed 13. It is also necessary to point out that in the case where variable output burners are used each row of burners which are fed jointly can be provided with a duct of the venturi type having a variable needle at

the junction of the feed pipes for the gaseous or liquid fuel and the combustion supporting gas such as air, the outlet pipe of the said duct going to the inlet of the said row of burners. This device is similar to that shown in Figure 4 for the test apparatus.

Also, instead of vertical axis burners shown in the attached drawing, horizontal axis burners may be used which would then be fixed on the vertical longitudinal walls of the hood, while taking the principles of distribution of the burners described above, into consideration.

WHAT WE CLAIM IS:

1. A method of firing a mixture of metallic ores and solid fuel comprising passing a bed of the mixture under a firing hood equipped with burners, maintaining a reduced pressure beneath the bed to draw firing gas from the hood burners through the bed, and supplying the burners with a fluid fuel and a combustion supporting gas containing oxygen, the delivery of firing gas to different regions in the hood being varied from the hood entrance to the hood exit in dependence on the permeability of that part of the bed below that region of the hood such that the pressure in the hood is maintained substantially constant, slightly above the ambient pressure, over the length of the hood.

2. A method according to Claim 1, in which the temperature of the firing gas is maintained between 1250°C and 1500°C by modifying the relationship between the delivery of fluid fuel and combustion supporting gas.

3. A method as claimed in Claim 1 or Claim 2, in which each cross-section of the bed is subjected to the firing operation during its stay beneath the hood for a period of between 30 seconds and 200 seconds.

4. A method as claimed in Claim 3, in which each cross-section of the bed is subjected to the firing operation for a period of between 50 and 70 seconds.

5. A method as claimed in Claim 3 or Claim 4, in which each cross-section of the bed is subjected to the firing operation for a period of substantially 60 seconds.

6. A method as claimed in any preceding Claim, in which the lower face of the mixture bed is not exposed to the action of the reduced pressure until the beginning of the passage of the bed beneath the firing hood, at which time the said mixture bed is subjected to the action of the firing gas.

7. A method as claimed in any preceding Claim, in which the variation in delivery of firing gas to different regions of the hood is obtained using the same number of burners in each region, the burners having variable outputs or different outputs from one another.

8. A method as claimed in any of Claims 1 to 6, in which the variation in delivery of firing gas to different regions of the hood is obtained with burners which all have the same output by providing a different number of burners in each different region.

9. A method as claimed in any preceding Claim, in which initially determined values of the delivery and temperature of firing gas are maintained during performance of the method and adjustments are made only by varying the reduced pressure applied to the lower face of the portion of bed located beneath the hood.

10. A method of firing a mixture of metallic ores and solid fuel substantially as described herein with reference to the drawings.

11. Plant for firing a mixture of metallic ores and solid fuel comprising a firing hood, means for transporting a bed of the mixture under the firing hood, burners in the firing hood for producing firing gas from fluid fuel and combustion supporting gas supplied thereto, means for producing a reduced pressure beneath the bed to draw firing gas from the hood burners through the bed, and means for feeding a fluid fuel and a combustion supporting gas to the burners in such a way that, together with the arrangement of the burners, the delivery of firing gas to different regions in the hood varies from the hood entrance to the hood exit in dependence on the permeability of that part of the bed below that region of the hood such that the pressure in the hood is maintained substantially constant, slightly above the ambient pressure, over the length of the hood.

12. A plant as claimed in Claim 11, in which at least the burners nearest the entrance end of the firing hood are mounted so as to be adjustable in height.

13. A plant as claimed in Claim 11, in which all the burners have substantially the same output and are grouped in rows, there being a greater number of burners in the rows nearer the entrance end of the hood than in the rows nearer the exit end of the hood.

14. A plant as claimed in Claim 11, in which all the burners in the hood have substantially the same output and the burners are arranged in rows each having the same number of burners, the distance between adjacent rows of burners increasing from the entrance end of the hood to the exit end of the hood.

15. A plant as claimed in any of Claims 11 to 14, in which the burners of a row are fed jointly with the aid of an adjustable venturi duct arranged at the junction of the fluid fuel feed pipe and the combustion supporting gas feed pipe, the outlet of the

said venturi duct leading to the feed inlet of the said row of burners.

16. Plant for firing a mixture of metallic ores and solid fuel substantially as described herein with reference to the drawings.

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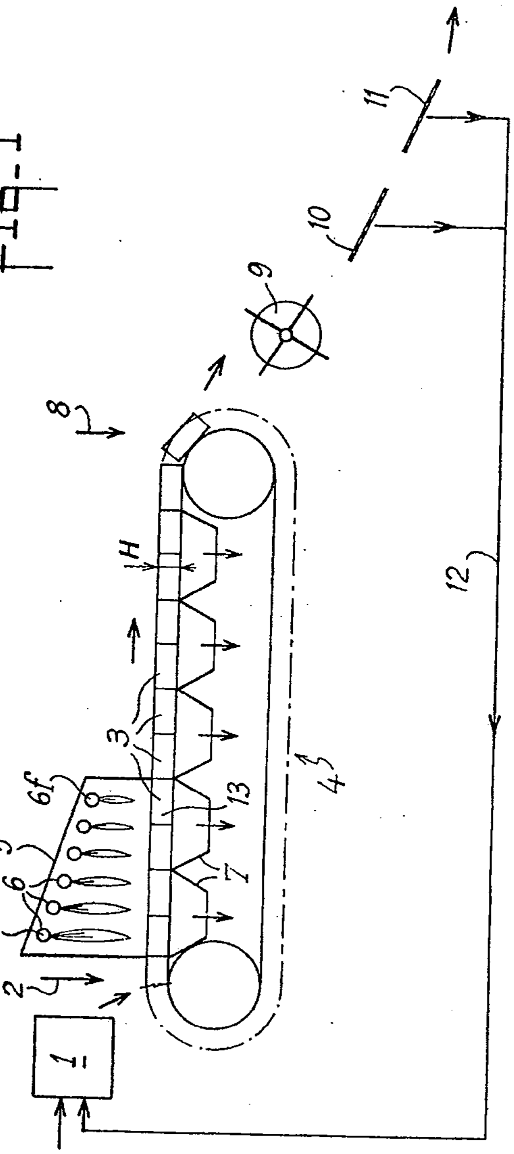
1574647 COMPLETE SPECIFICATION

5 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

Fig-1



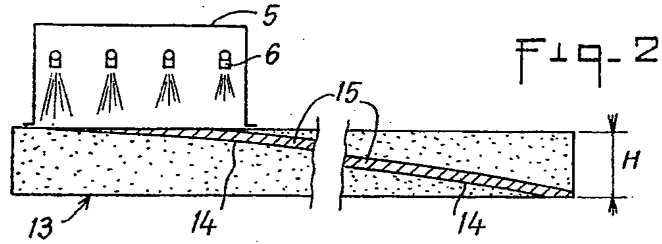


Fig-2

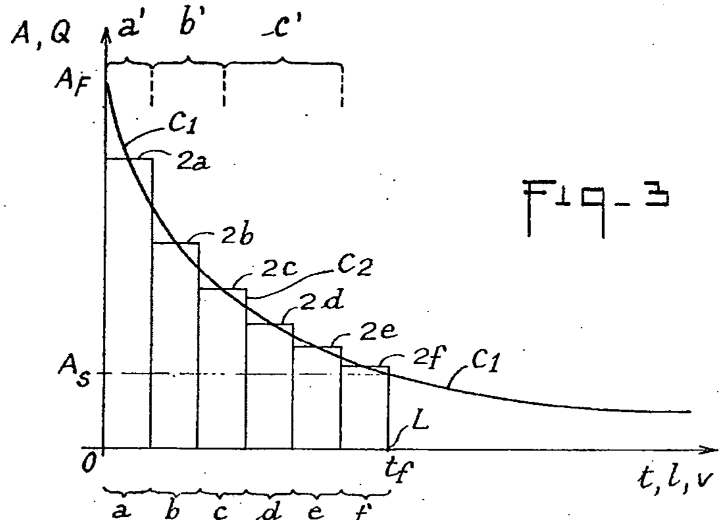


Fig-3

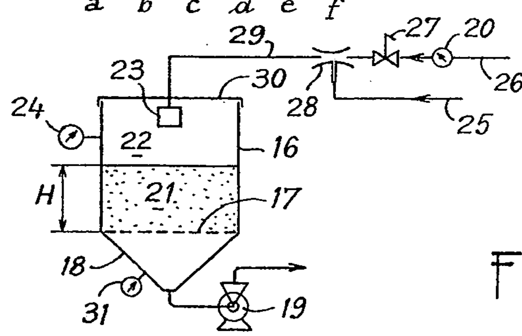


Fig-4

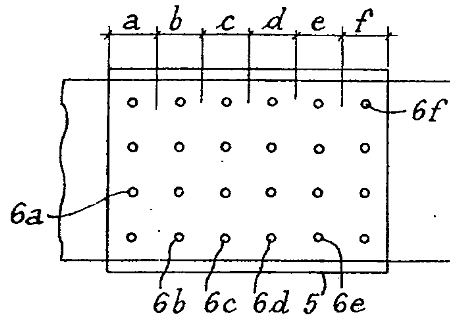


Fig. 5

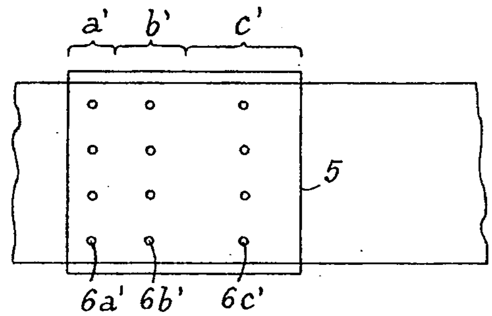


Fig. 6

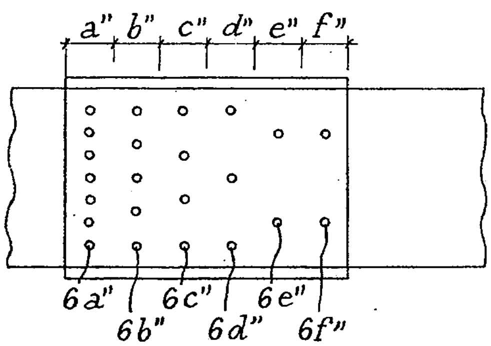


Fig. 7

Fig-8

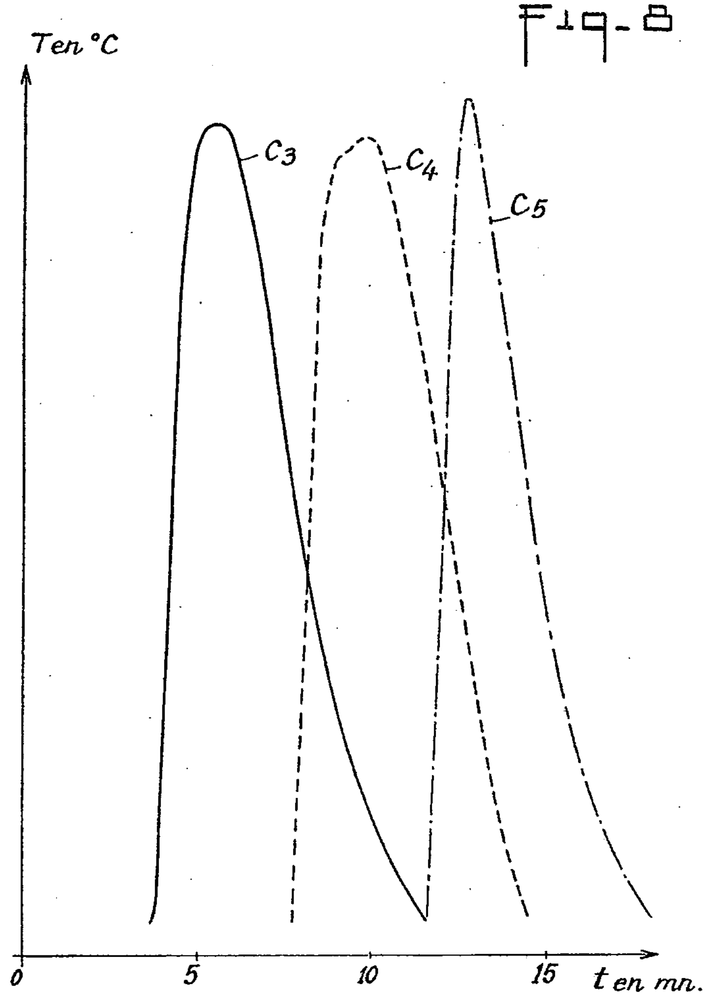


Fig-9